Build a Simple Infrared Illuminator

by Fernando Garcia

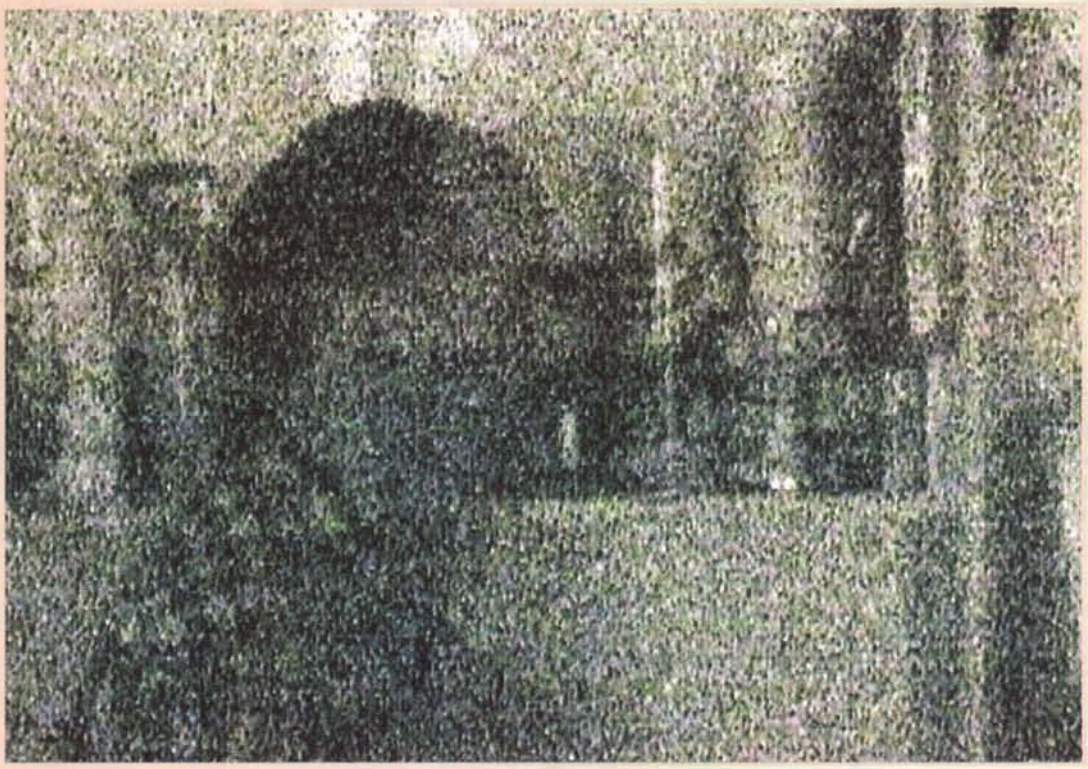

Photo 1: Un-retouched photo taken in almost complete darkness.

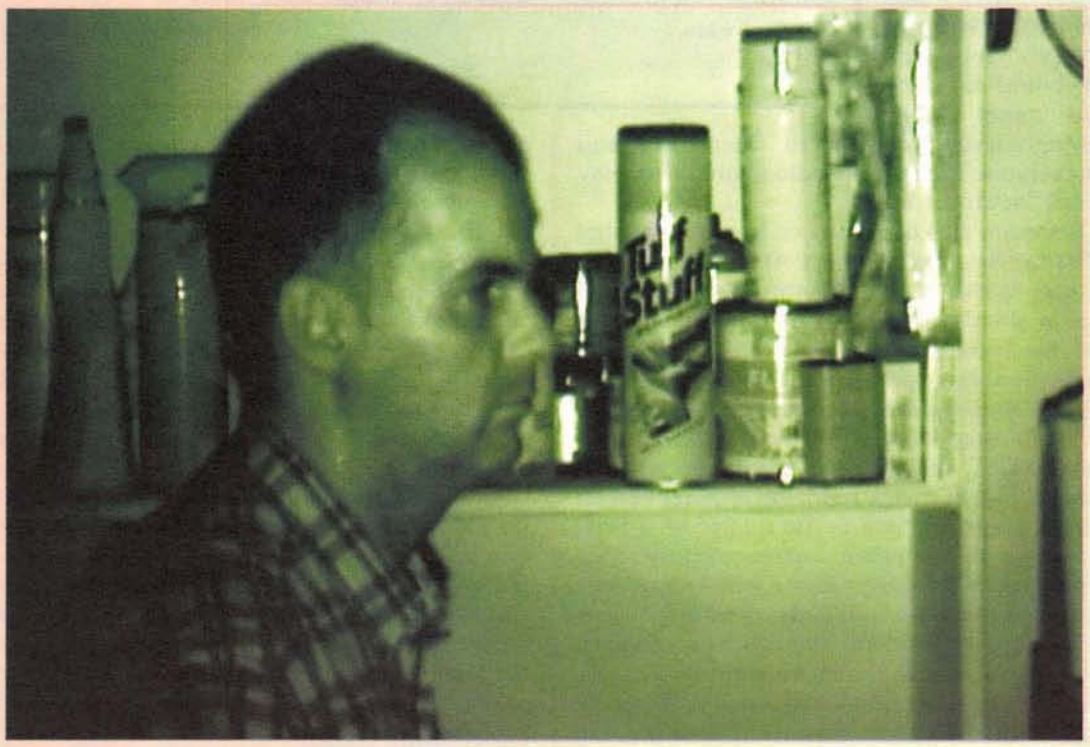

Photo 2: Same environment, but with the IR illluminator turned on. For the person, it still was almost complete darkness.

Video cameras have both shrunk their size and reduced their cost thanks to CCD (Charge Coupled Device) technology. Applications previously considered beyond the reach of the average person are now easily accessible.

One of the most fascinating applications is the capability to see in the dark. From surveillance systems to wildlife observation, nighttime conditions offer very exciting viewing conditions.

Actually "seeing in the dark" is a misnomer. Although newer CCD cameras can see to illumination levels below 1 lux, there still must be some sort of radiated energy for the camera to see. The good news is that we need not constrain ourselves to visible light radiation, most B/W and a few color CCD cameras are also sensitive to IR (infrared) radiation.

Therefore, we can illuminate an area with IR light, while maintaining the darkened condition (from the eye's perspective), but allowing the camera to "see in the dark." The project described here is a simple-to-build, battery-powered IR illuminator that will allow precisely that.

From surveillance systems to wildlife observation, nighttime conditions offer very exciting viewing conditions.

Infrared light is that part of the spectrum whose wavelength is between about 700 nanometers (red color) to about 100 micrometers (microwaves). The longer wavelength limits are known as far-infrared and is what we perceive as heat. Although sensors do exist that allow to actually detect heat (for true, see-in-the-dark capabilities), the low-cost cameras and IR LEDs operate in the near-infrared range. This range is just below the color red to about 1,500 nanometers. This project operates in the near-infrared range.

A stunning result of what this project can achieve is shown in Photos 1 and 2. Photo 1 shows the video output of a camera operating under very low light conditions. The extremely noisy picture shows a shadow moving into a garage area. There is no doubt that somebody is lurking there, but the complete lack of detail does not allow you to determine whether the person is a friend or not. Photo 2 – under the exact same darkened conditions, but with the IR illuminator turned on – now shows up substantially clearer. Although the picture is still grainy, the detail is enough to allow reading of some labels and to see the person which happened to be (fortunately!) a friend.

Before you attempt to build this project, a simple experiment is recommended to determine whether your video camera is IR-compatible or not. In a darkened room, illuminate a small area with the IR light coming from your TV or VCR's

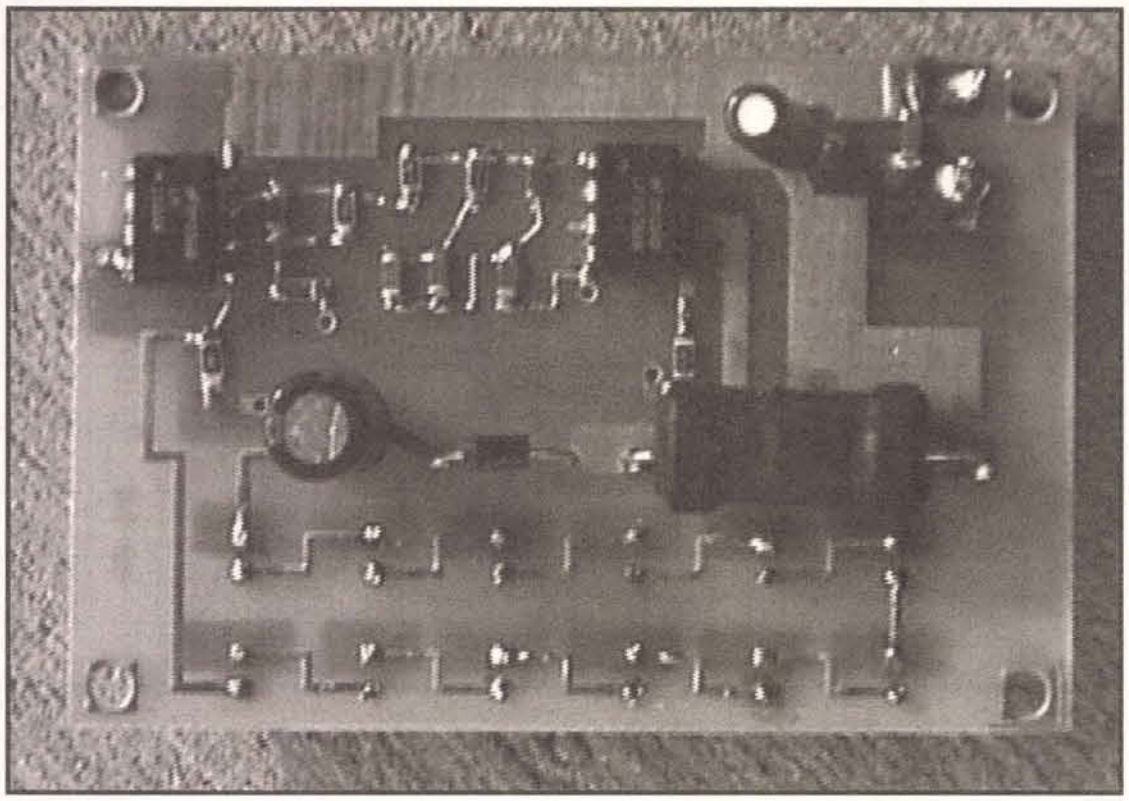

Photo 3: Assembled board, component side.

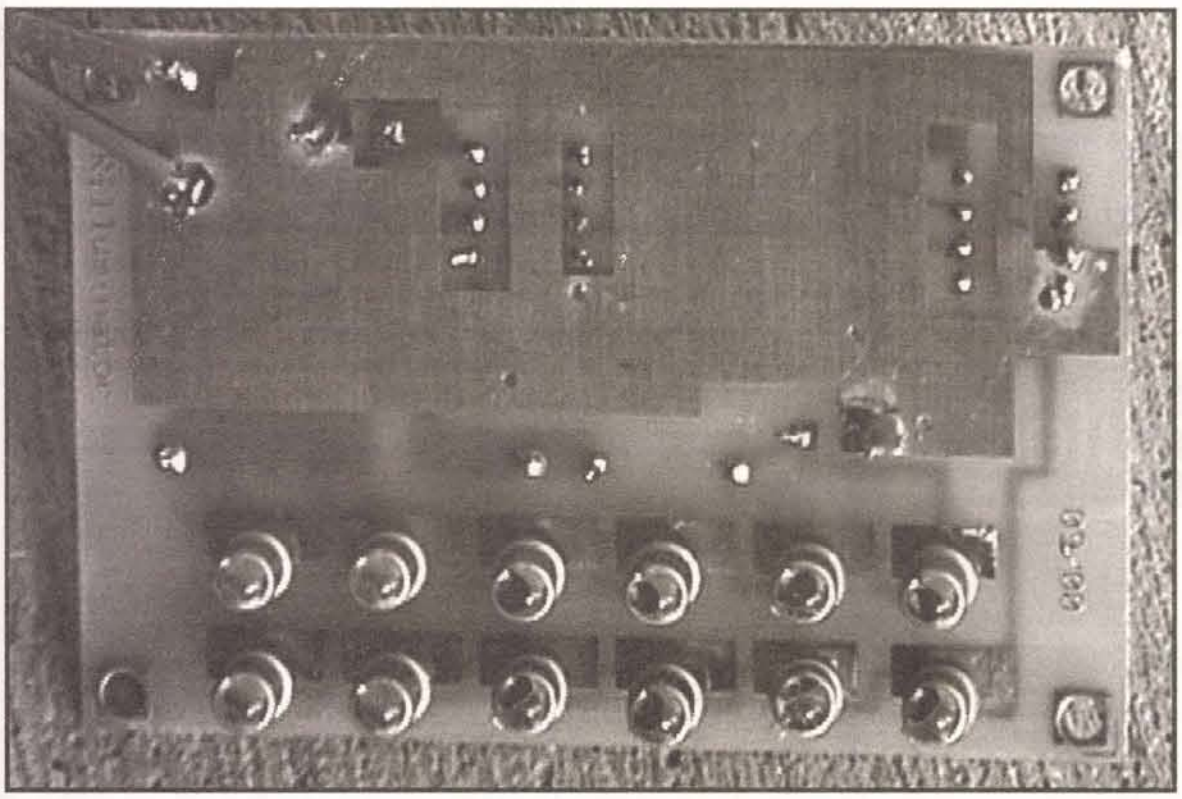

Photo 4: Assembled board, solder side. Note the IR LEDs.

remote control. These devices employ IR LEDs to transmit signals, and if you can see the flashing light through the viewfinder, then the camera is suitable for this project.

Circuit Description

LEDs are current-driven devices, and therefore cannot be connected across a voltage source – like a battery – without some current limiting device. In its simplest form, this is a resistor.

Although a very inexpensive solution, it suffers the drawbacks of poor current regulation with a varying input voltage and the waste of a large amount of energy. This is important if we plan the circuit to be portable, meaning batteries will supply the power.

A linear regulator in a constant current mode would avoid the current variations but is also very wasteful, dissipating most of the battery's power as heat. Therefore, a switch mode regulator was chosen for this project. The circuit described here maintains a 1% current regulation over an input range of 9 to 14 volts, while still maintaining 87% efficiency.

The selected switch mode regulator is the LM3578, part of National Semiconductor's Simple Switcher® family. The devices in this family are extremely versatile and easy to use, and all include a flexible PWM controller and a transistor power switch integrated within the same silicon die. Only a few passive components are required to build a complete supply.

Unlike its cousins with fixed frequencies, the LM3578 regulator (U1) allows the switching frequency to be set externally. As shown in the schematic of Figure 1, this is achieved with capacitor C2 for a frequency in the neighborhood of 80 kHz. This versatile device also permits the power transistor switch to be connected in a variety of configurations. In this circuit, the device is connected as a boost topology. The boost topology always produces an output voltage higher than the input.

This is required because the series-connected string of IR-LEDs (D2 through D13) will have a combined voltage drop between 17.5 and 20 volts – a voltage larger than the battery voltage range for which we expect the circuit to work.

The boost converter works by storing energy on inductor L1 during the power switch "on" time, and then releasing it in series with the battery during the "off" time by means of Schottky diode D1. The energy

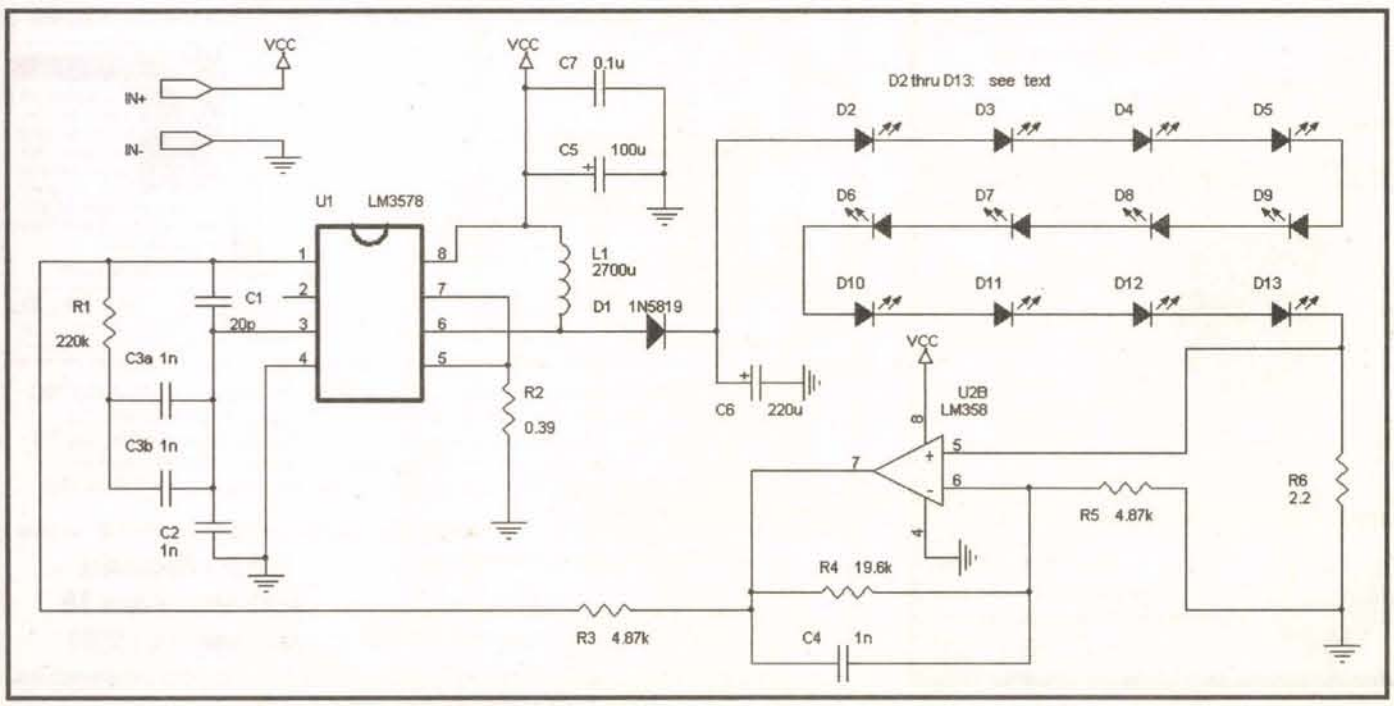

Figure 1: Project Schematic. U1 is a "Simple Switcher" from National.

pulses are delivered to capacitor C6 which smoothes out the voltage. To prevent damage during an overload condition, resistor R2 senses the current across the switch, and disables the circuit if its voltage drop exceeds 110 millivolt. C1, R1, C3, and R3 are a loop compensation network required for stability.

So far, all the above description has been textbook circuitry right from National's data sheet. What is different in this application is the feedback circuit. As previously mentioned, for a LED load, we require a constant current regulator. Therefore, we need to take a LED current sample, which is accomplished by R6.

To maintain a high efficiency, the voltage drop across R6 should be a small fraction of the total LED voltage drop. Unfortunately, U1 requires a feedback level of around one volt, which would mean a 5% to 6% efficiency penalty in the current sense resistor. Therefore, operational amplifier U2 and resistors R4, R5 provide the necessary voltage gain of around five to employ a much smaller current sense resistor. Capacitor C4 provides high frequency roll-off to prevent switching noise feeding into the feedback loop.

With the values shown, the LED current is regulated to approximately 90 milliamps. The higher the current, the brighter the LED will shine, but we must be careful not to exceed the maximum steady state current rating of 100 milliamp. The chosen current level provides a safety margin while maximizing the light output.

A few words about IR LEDs: There are two commonly available families of IR LEDs, depending on its peak wavelength and semiconductor material. This is shown in Figure 2. The AlGaAs devices usually have a peak spectral response around 880 nanometers. On the other hand, GaAs devices have a peak response around 940 nanometers.

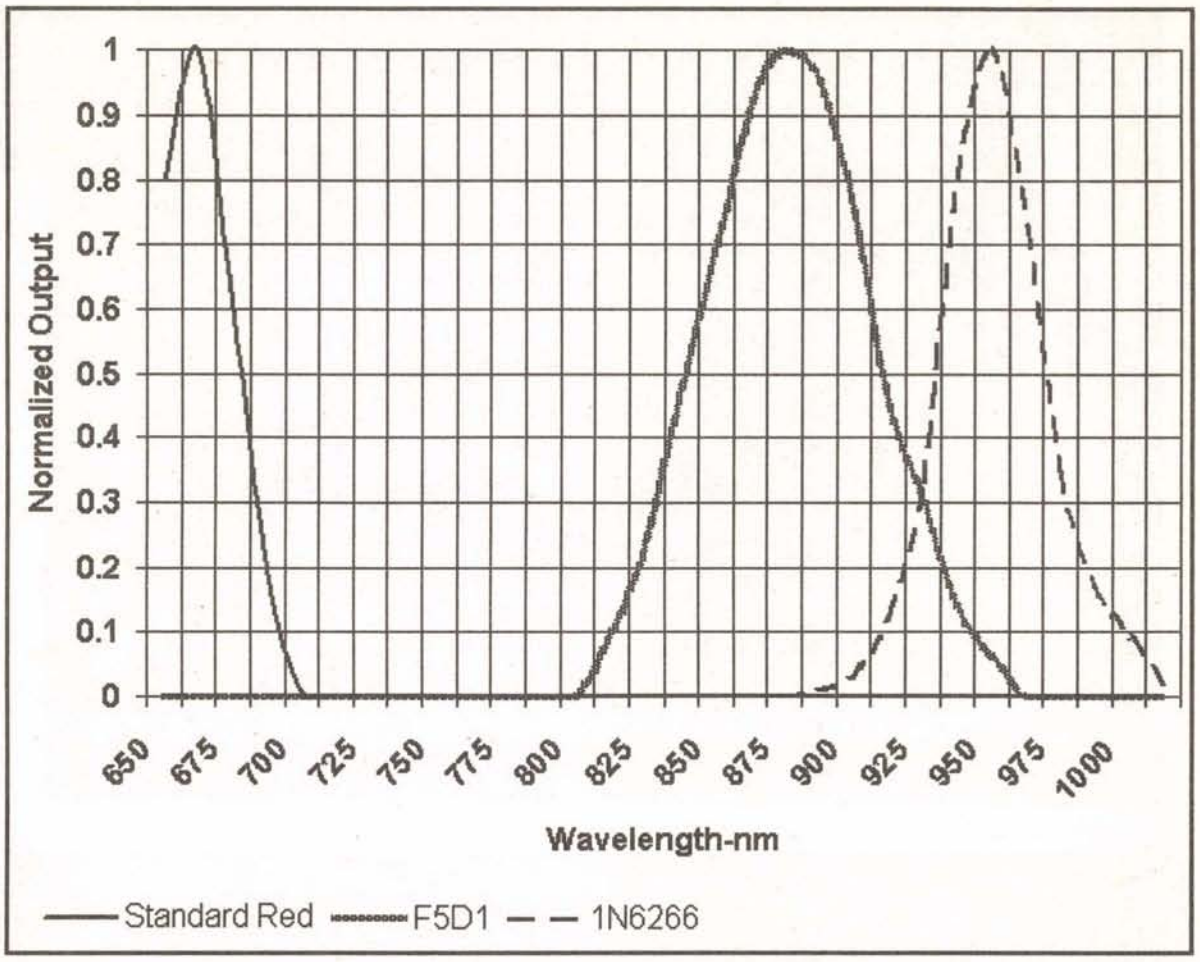

Figure 2: Infrared LED response. A standard red LED response is shown as a reference.

The response of a 660 nanometer, "standard" red LED is shown for comparison purposes. In general, the longer wavelength LED devices are

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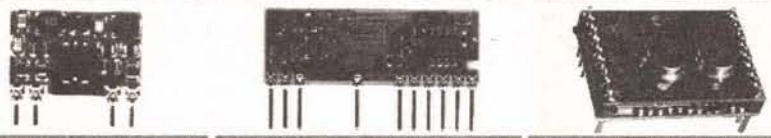

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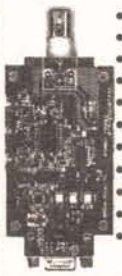

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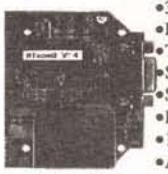

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more efficient in converting current into light. Therefore, a 940 nm device such as the 1N6266 would provide greater illumination capability than the 880 nm device such as the F5D1. The caveat could be if the camera's response has decreased excessively at this wavelength, which may offset any LED efficiency improvement.

Since the LEDs will be the highest cost in this project, it pays to procure one of each type, wire both in series and, with your camera, determine which one appears the brightest.

Assembling the Circuit

Due to the fast risetime of the switching waveforms, it is almost mandatory to use a printed circuit board for this project, with wide traces and good ground planes. A double-sided sample board used by the author is shown in Figure 3.

With the exception of the LEDs, all the components go on the top side of the board, as shown in the silkscreen. Most of the devices employed in this project are surface mount technology (SMT) components for several good reasons: not only do they allow a more compact layout, but for a high frequency switching circuit, they have far fewer parasitics.

A few thru-hole components are also employed. A view of the board's top side is shown in Photo 3. The LEDs are mounted on the bottom side of the board, as close as possible to the board itself without actually touching it. The reason being that at the high operating current, the LED themselves will become fairly warm, and the board's copper lands act as a small heatsink, see Photo 4. However, do not solder the LEDs flush to the board, leave about 1/16-inch spacing between the board and the LEDs themselves.

First, it will allow some play such that you can slightly aim the beams. Second and most important, the LED anode is electrically connected to the metallic case, and if the case touches the cathode pad, no damage will occur, but that LED will not light up. And since it emits invisible light, you will not notice!!

The specified LEDs have a built-in lens, which solves one of the more vexing problems facing the assembler of the circuit; namely how to focus a beam of infrared light. The lens focuses each individual beam in a fairly narrow angle, and thus the complete LED array will illuminate an area similar to what a three-inch reflector flashlight would do. As mentioned previously, the LED spacing will allow some alignment of the beam.

One word of caution: To maximize efficiency, the circuit does not include reverse-battery protection. Connecting it to the wrong polarity will certainly damage the circuit. If you require reverse polarity protection, include a Schottky diode such as a 1N5817 in series with the (+) input lead. **NV**

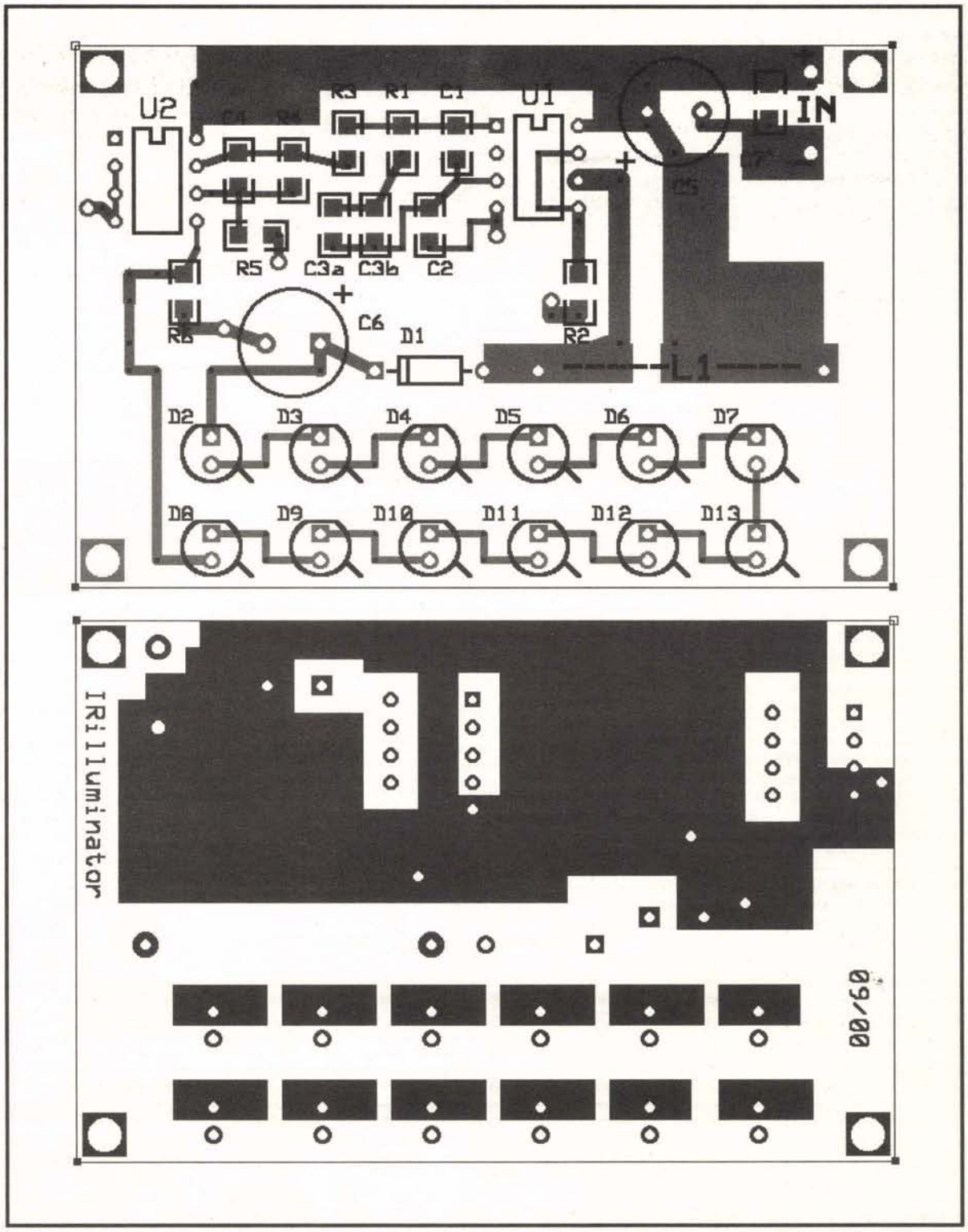

Figure 3: Double-sided board layout. Component side (top), and solder side (bottom). The IR LEDs are placed on the solder side, see Photo 4.

Parts List

Semiconductors:

U1	LM3578N switchmode regulator
U2	LM358 op amp
D1	1N5819 Schottky diode
D2 - D13	1N6266 or F5D1 Infrared LED (see text)

Resistors (1206 size SMT, 1%)

R1	220k ohm
R2	0.39 ohm
R3, R5	4.87k ohm
R4	19.6k ohm
R6	2.2 ohm

Capacitors

C1	20 pF, 5% ceramic 1206 size SMT
C2, C3a, C3b, C4	1 nF, 5% ceramic 1206 size SMT
C5	100 uF, 16V electrolytic
C6	220 uF, 25V low-Z electrolytic
C7	0.1 uF 20% ceramic

Miscellaneous

L1	2700 uH, 500 mA inductor

Wire, PC board, 12-volt (nominal) battery

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